

The Community Earth System Model: A Framework for Collaborative Research

www.cesm.ucar.edu



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The Community Earth System Model

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Outline

- Overview and Community Involvement
- Major Activities and Achievements
 - ✓ Model releases and CMIP5
- Selected Science Highlights
 - ✓ Improved Variability
 - ✓ Future Climate Simulations
 - ✓ Data Assimilation
- Best Practices and Challenges

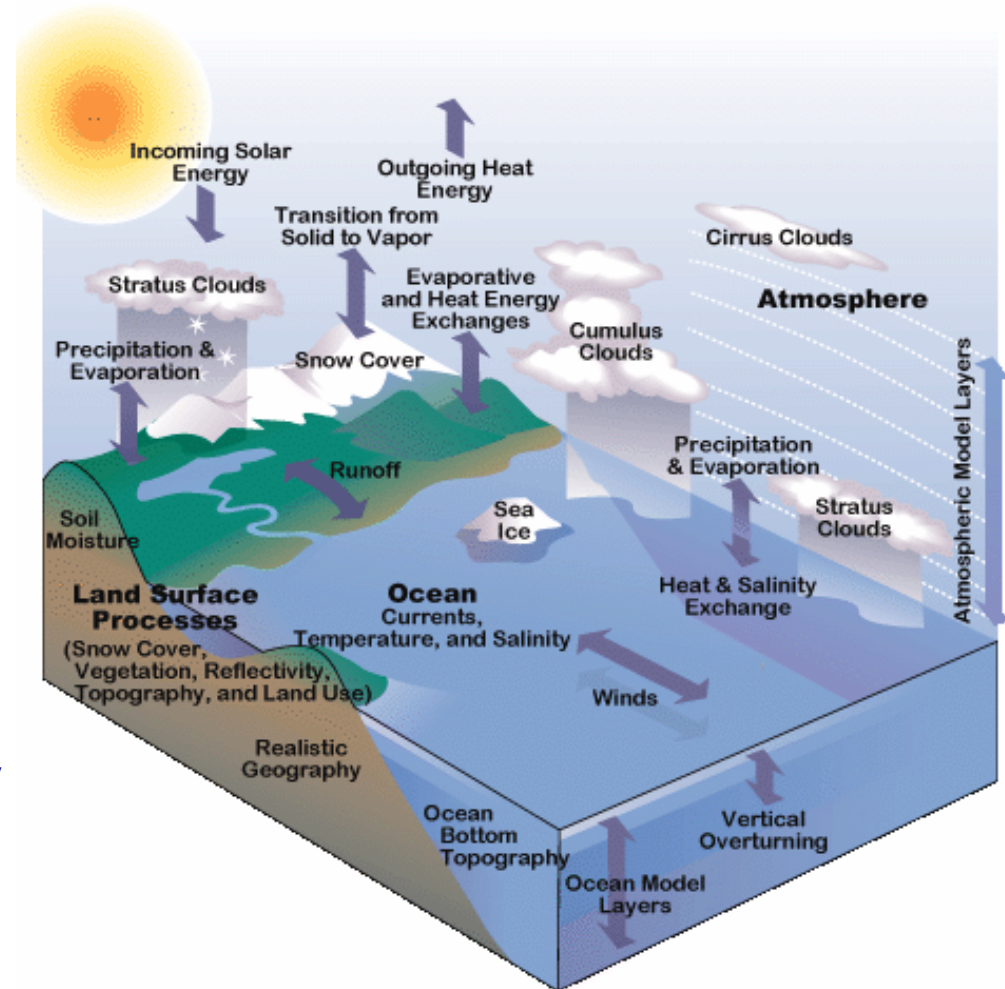


The Community Earth System Model

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- CESM: a set of different geophysical component models that exchange boundary data via a coupler
- Code base developed over 20+ yrs: runs on multiple platforms, resolutions and model configurations
- CESM is used to:
 - Explore Earth climate history and processes responsible for variability and change
 - Estimate future of environment for policy formulation
- Developed by NCAR NSF, DOE, Universities, National Laboratories
- Fully documented, frequently and freely distributed, fully supported releases
- Capacity Building (e.g., tutorials and workshops)

Modeling the Earth System



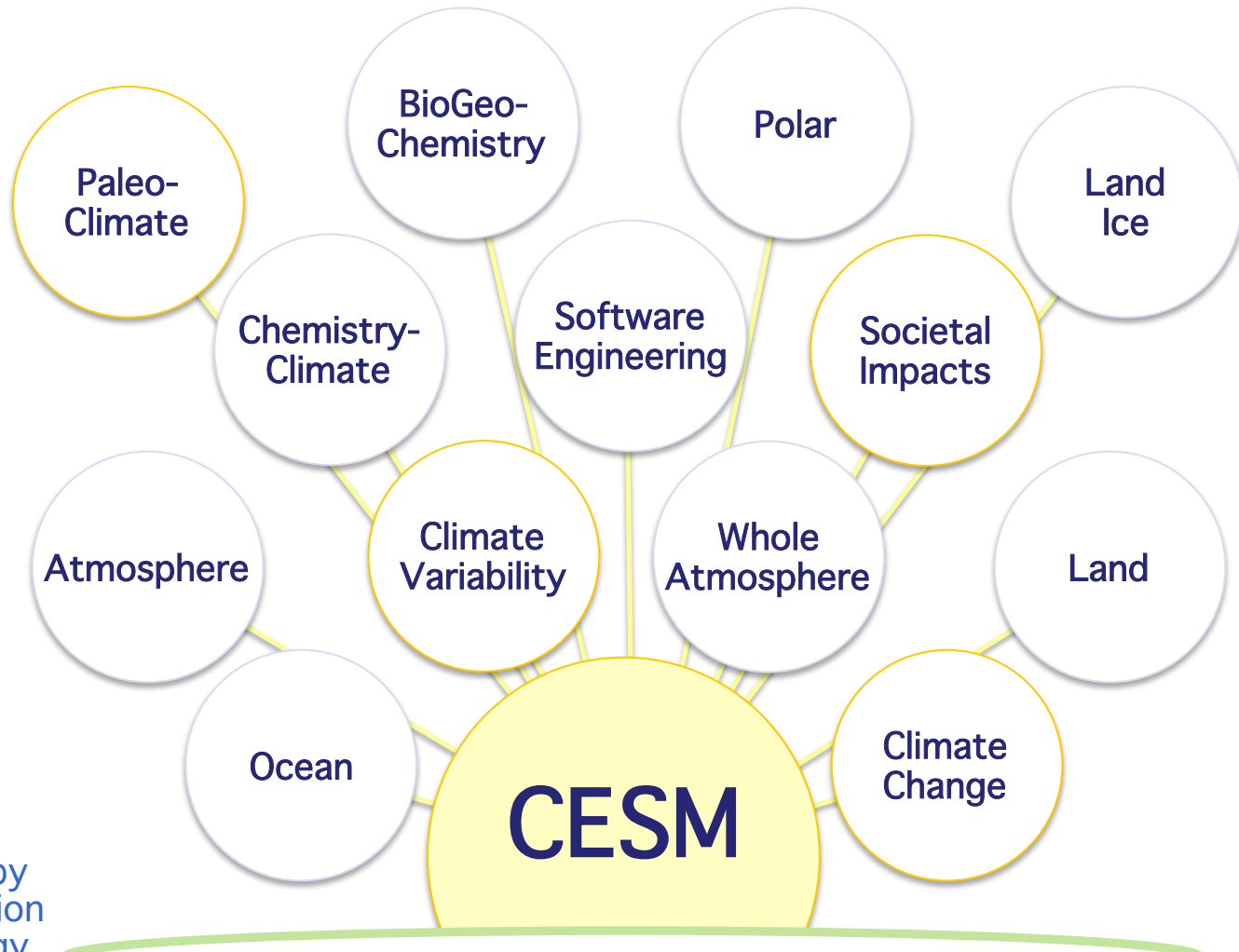
Community Involvement: CESM Management

CESM Advisory Board

CESM Scientific Steering Committee

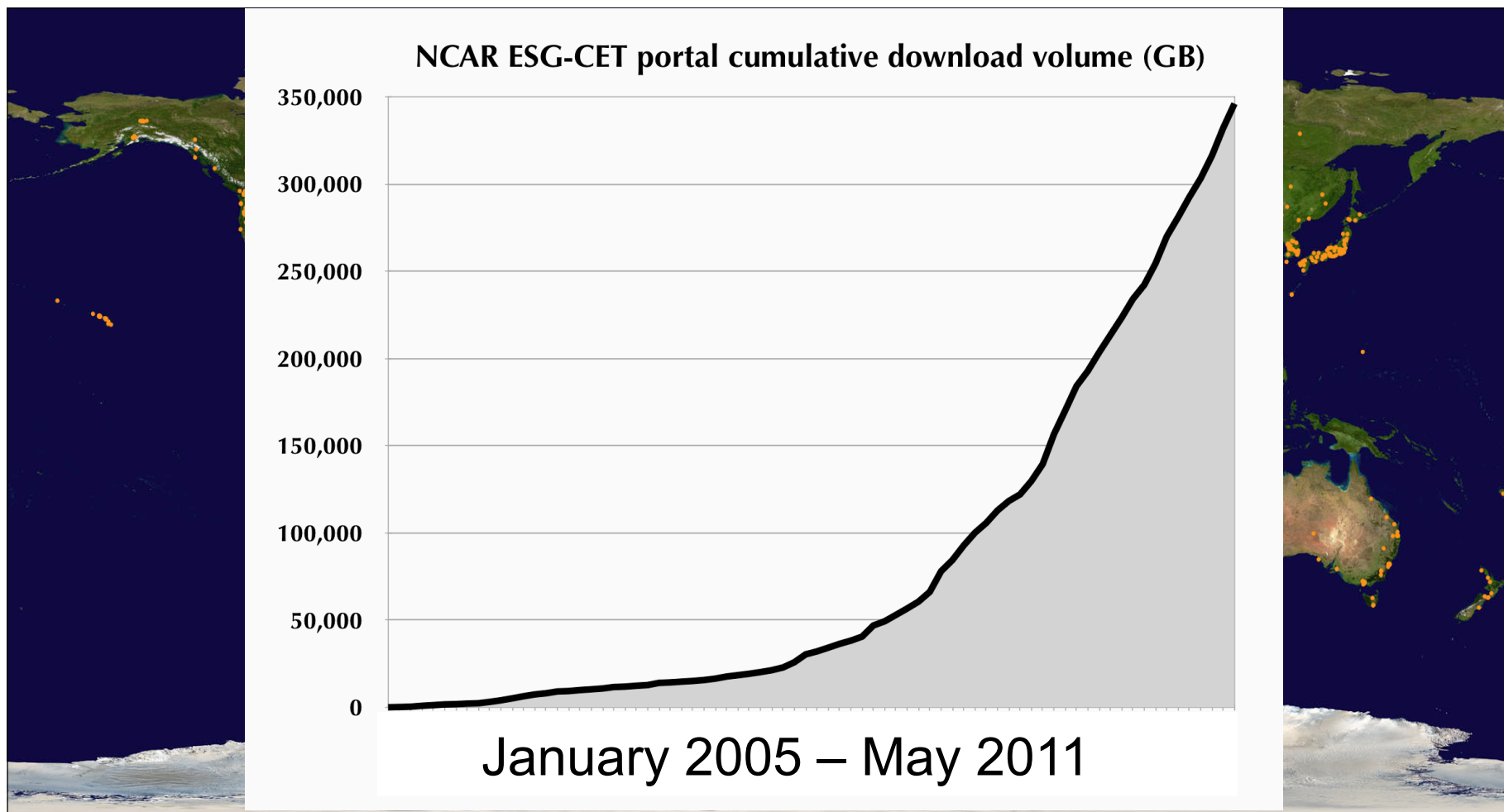


CESM is primarily sponsored by the National Science Foundation and the Department of Energy



<http://www.cesm.ucar.edu/management>

A Community Resource



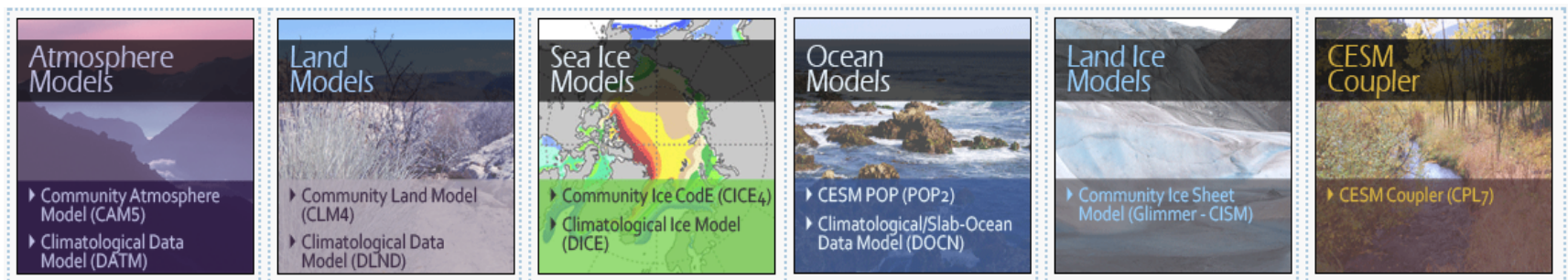
Over 3,000 sites from 130+ countries
>320 TB since January 2008
>1500 Registered Users of CESM1.0

Courtesy Gary Strand

Major Activities and Achievements

CESM Releases and Simulations

- CESM release mechanism
 - ✓ New release infrastructure: code, diagnostics and input data are obtained via subversion servers
 - ✓ First version of CESM and supporting documentation was released for community use in June 2010 (CCSM4.0 in April 2010)
 - ✓ Enhanced documentation, diagnostics and revamped web pages



- Benchmark and CMIP-5 simulations
 - ✓ Control, historical, initialized decadal prediction and climate change
 - ✓ CCSM4.0 and CESM (CAM5, CAM-CHEM, WACCM, BGC)
 - ✓ All Core, and most Tier 1/2, experiments complete & available (ESG)

CESM Experiments and Diagnostics

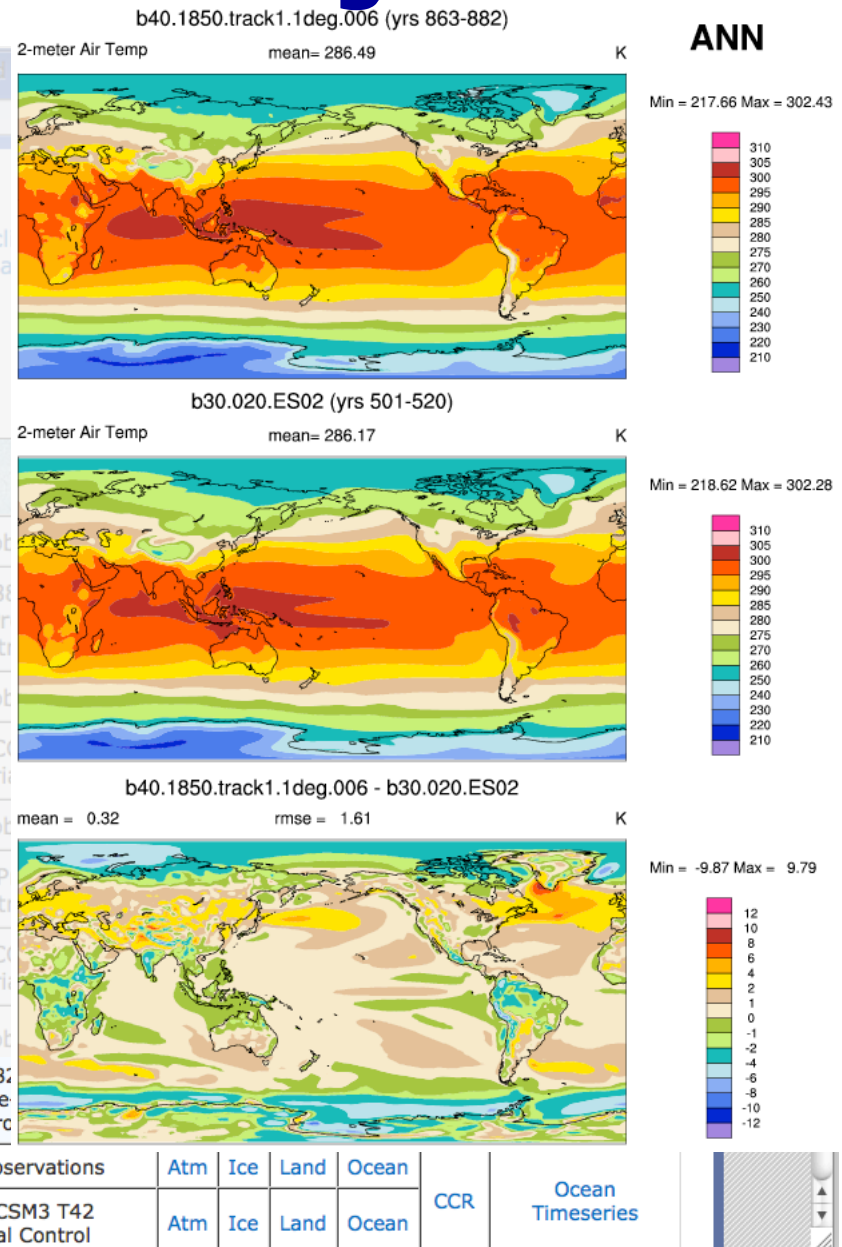
CESM1.0 Experiments and Diagnostics

<http://www.cesm.ucar.edu/experiments/cesm1.0/>

Jump To: Control Simulations 20th Century All-Forcings Simulations 20th Century Single-Forcings Simulations RCP Simulations CO2 Simulations Paleocl Simulations

CONTROL SIMULATIONS

Brief Description	Case Details	
CCSM4 1° Pre-Industrial Control Case Name: b40.1850.track1.1deg.006 Data Location: ESG	Details	863-892 w/obs CCSM3 T85 Pre-Industrial Control
CCSM4 2° Pre-Industrial Control Case Name: b40.1850.track1.2deg.003 Data Location: ESG	Details	501-530 w/obs 501-520 - CCSM3 T42 Pre-Industrial Control
CCSM4 T31 Pre-Industrial Control Case Name: b40.t31x3.037 Data Location: ESG (451-500)	Details	451-500 w/obs 451-500 - 2° Pre-Industrial Control 451-500 - CCSM3 T42 Pre-Industrial Control
CCSM4 2° Pre-Industrial Control Case Name: b40.1850.track1.1deg.006 Data Location: ESG	Details	863-892 w/obs CCSM3 T85 Pre-Industrial Control
CCSM4 2° Pre-Industrial Control Case Name: b40.1850.track1.2deg.003 Data Location: ESG	Details	501-530 w/observations 501-520 - CCSM3 T42 Pre-Industrial Control



Many New Results and Capabilities

Special Collection J. Climate Papers:

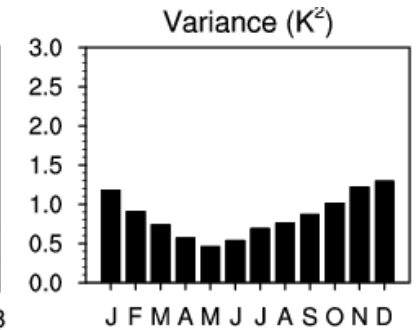
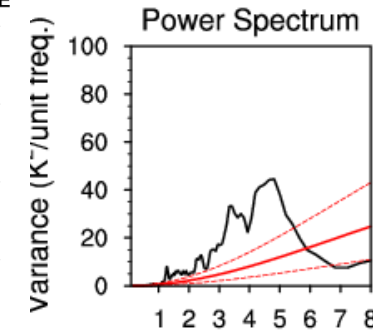
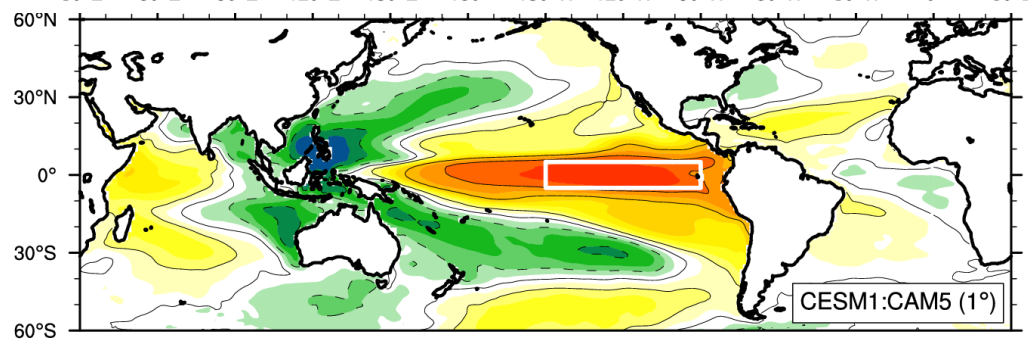
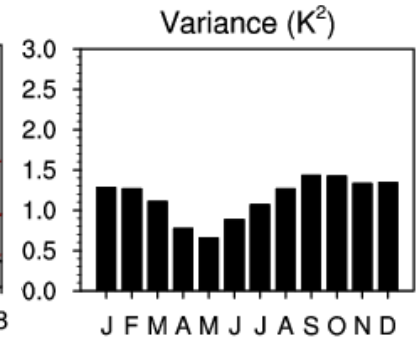
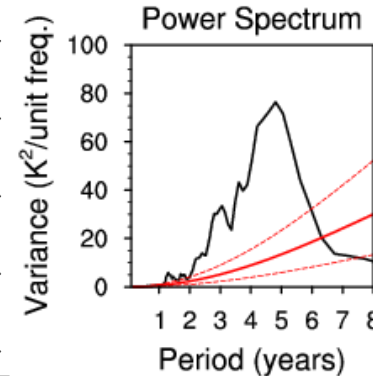
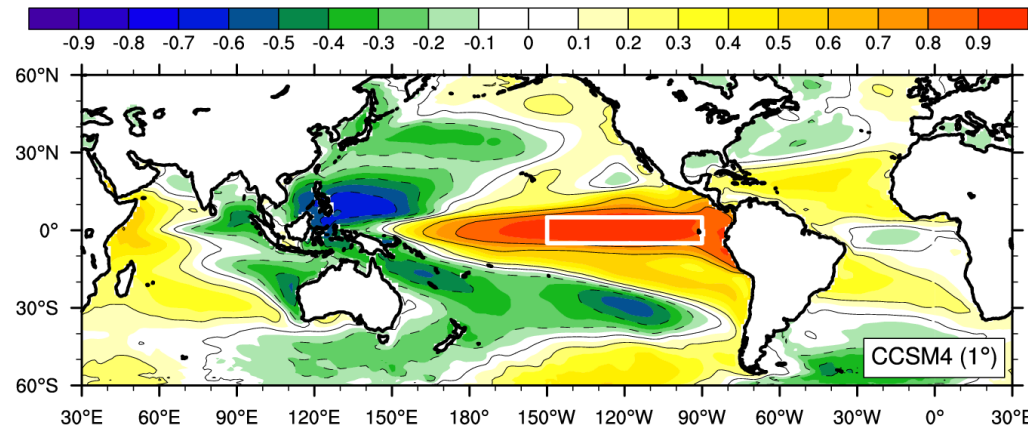
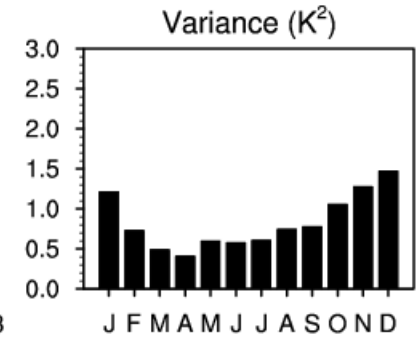
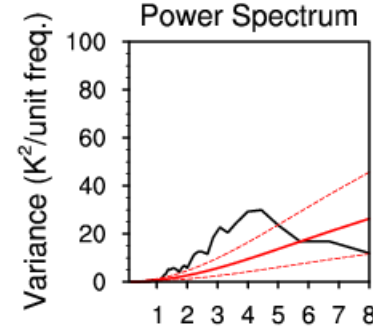
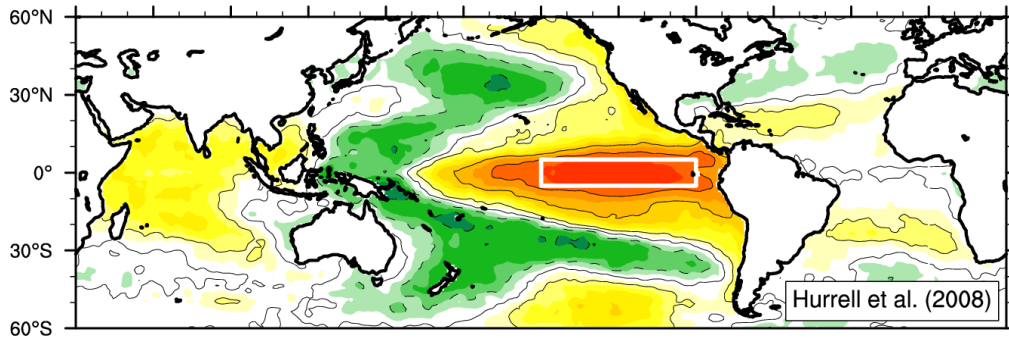
<http://www.cesm.ucar.edu/publications/pub.info.html>

or at AMS:

<http://journals.ametsoc.org/page/CCSM4/CESM1>

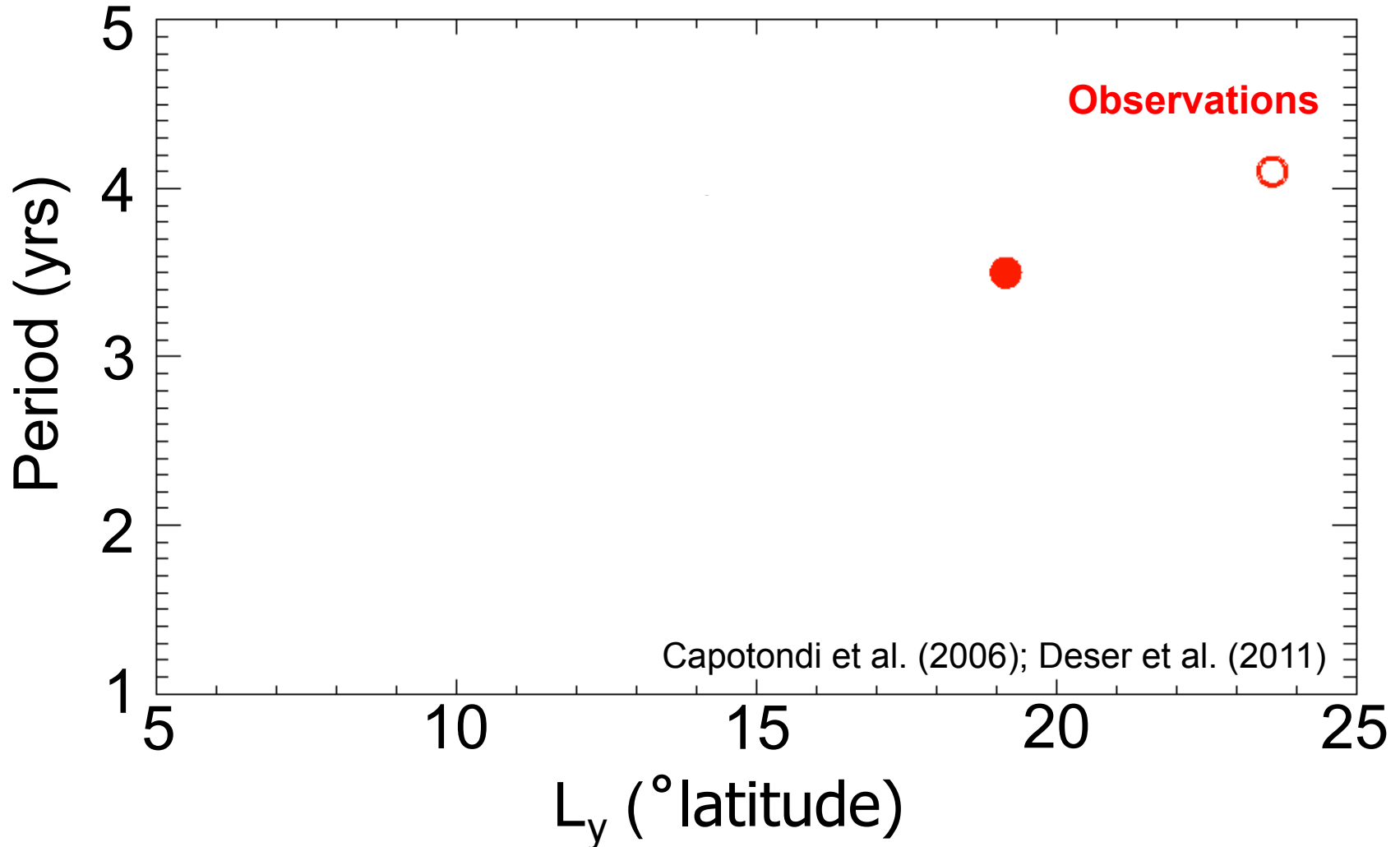
Selected Highlights: Improved Variability

Pacific Variability: ENSO



Neale et al. (2008); Deser et al. (2011); Gent et al. (2011)

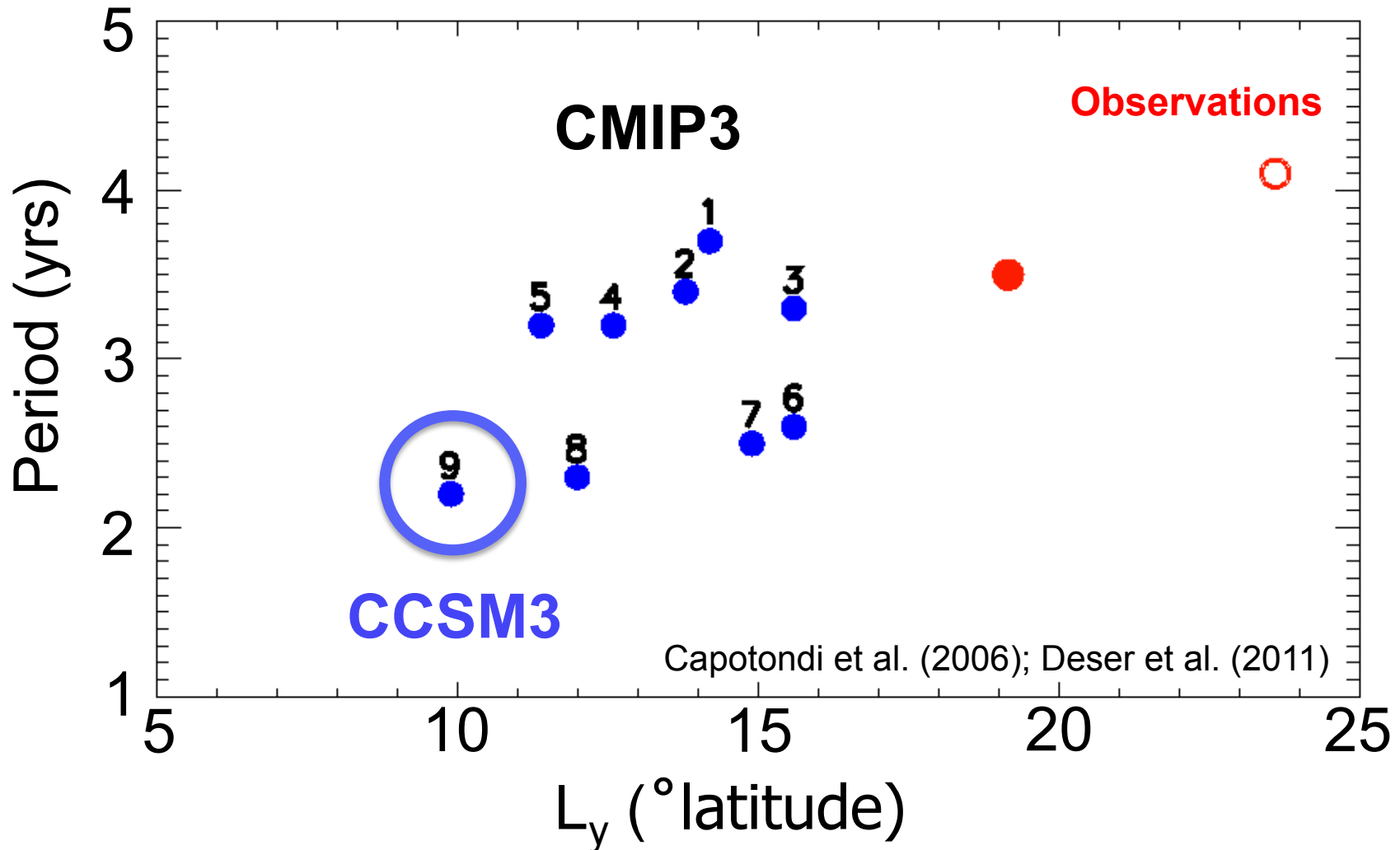
ENSO in CCSM4 and other models



Period → freq of max spectral power of Niño3.4 SST

L_y → width of zonal wind stress anomalies

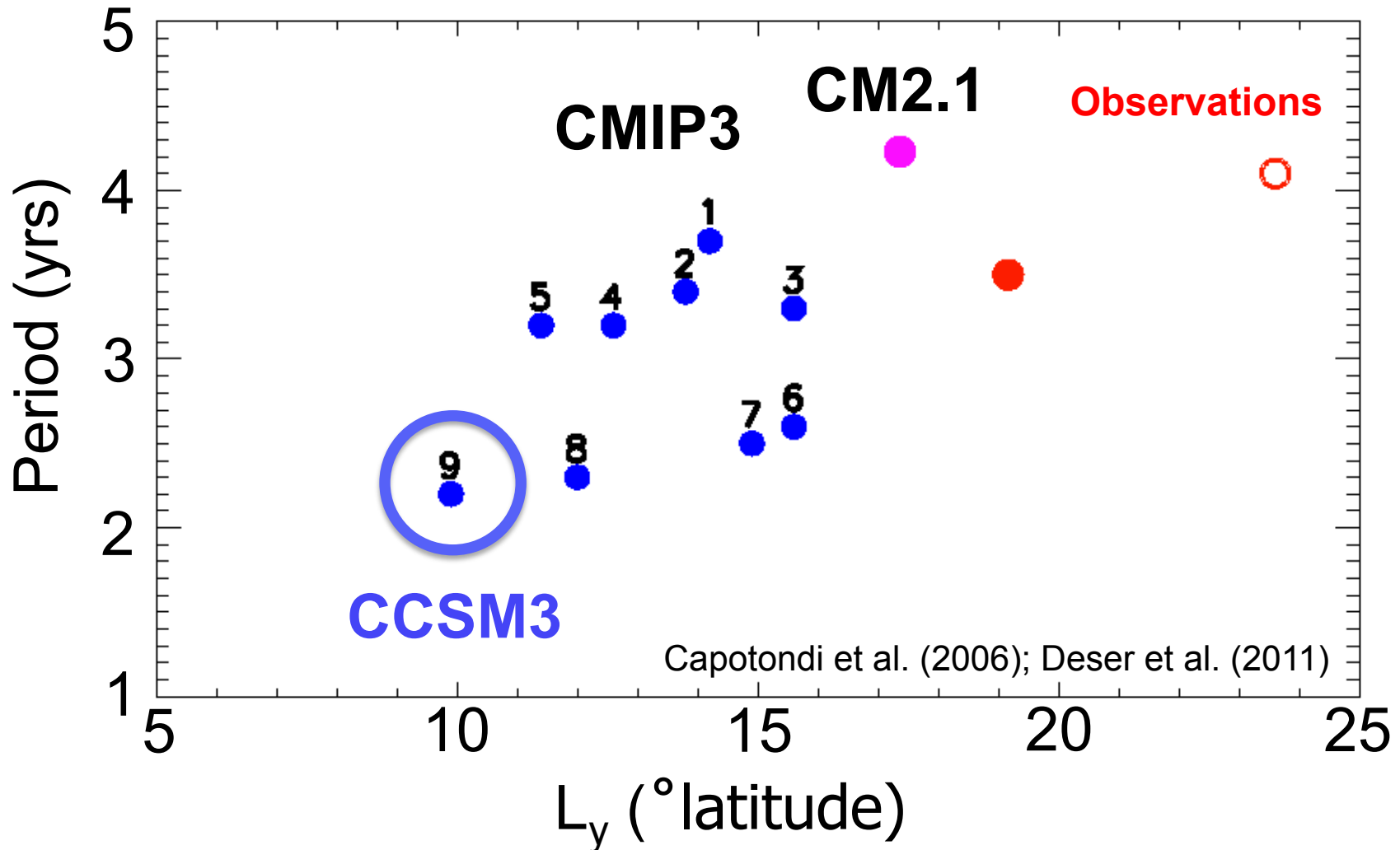
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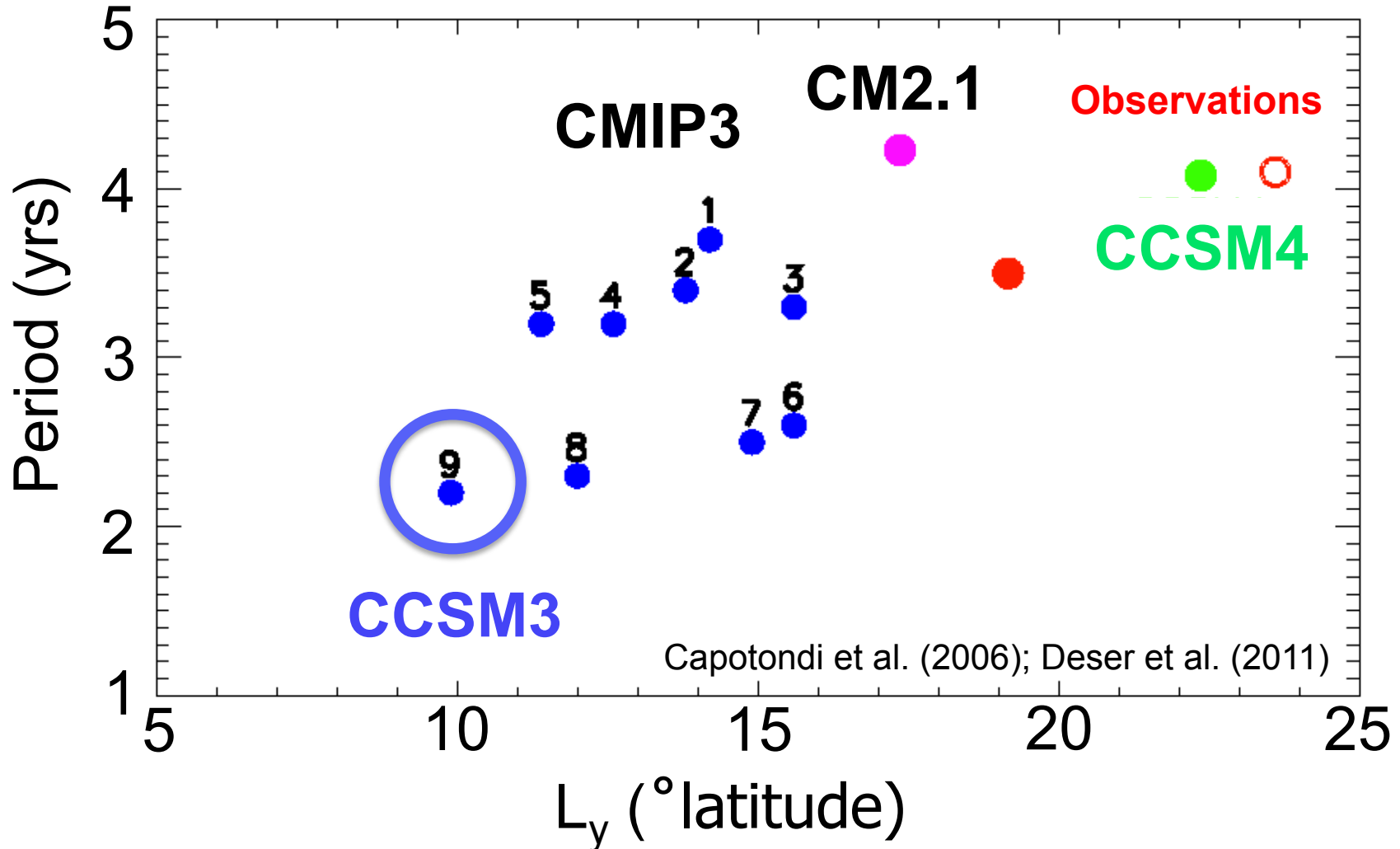
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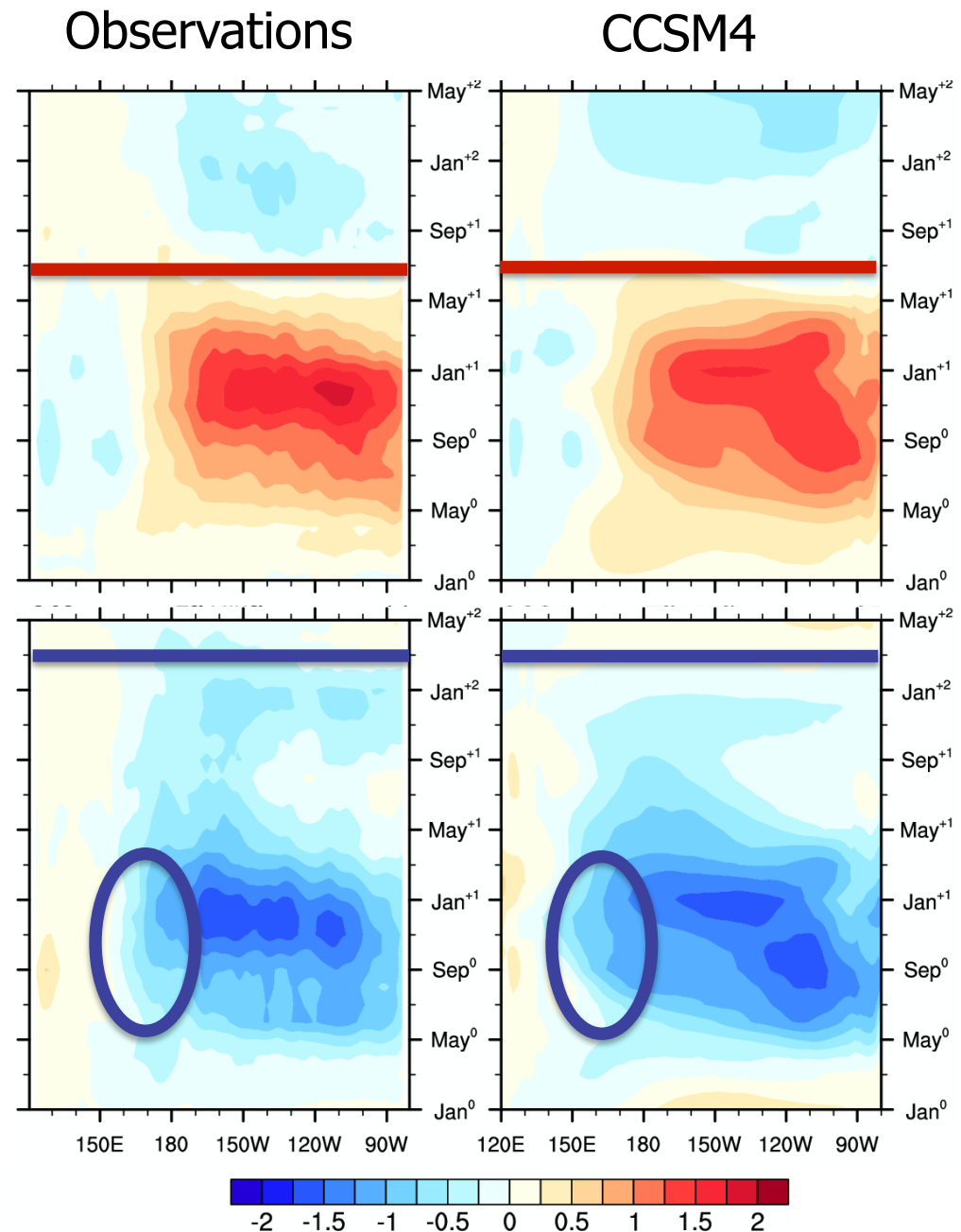
L_y \rightarrow width of zonal wind stress anomalies

Equatorial SST Composites

El Niño

Latitude/Time
cross-sections

La Niña



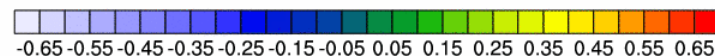
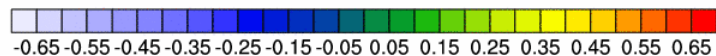
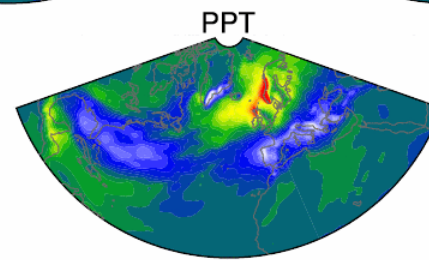
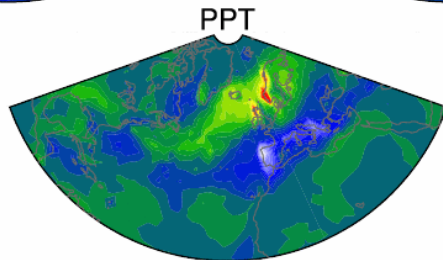
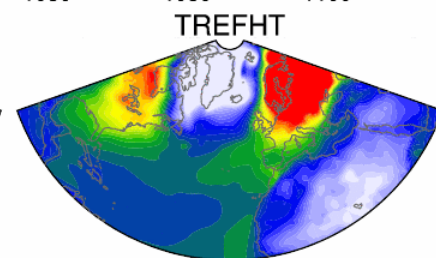
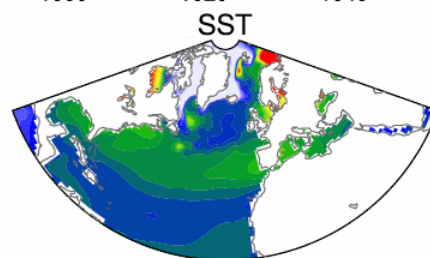
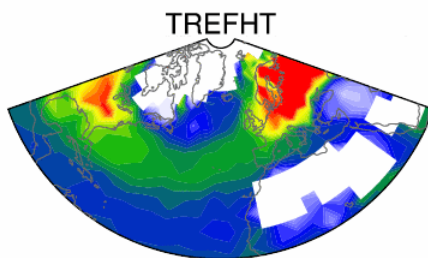
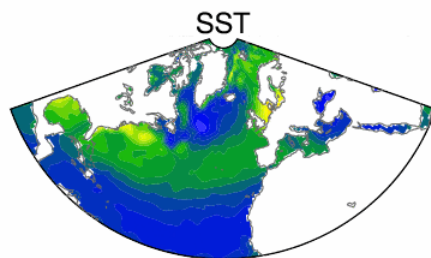
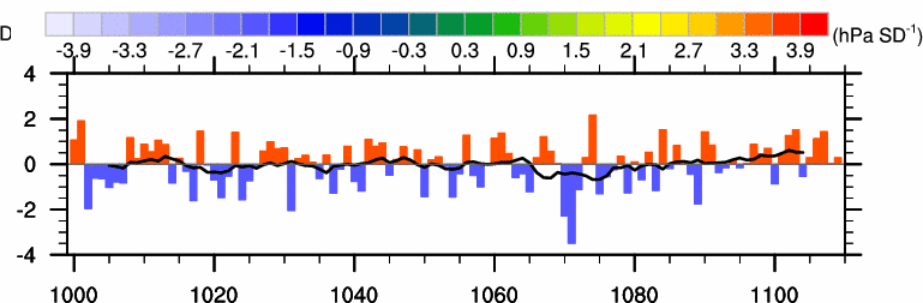
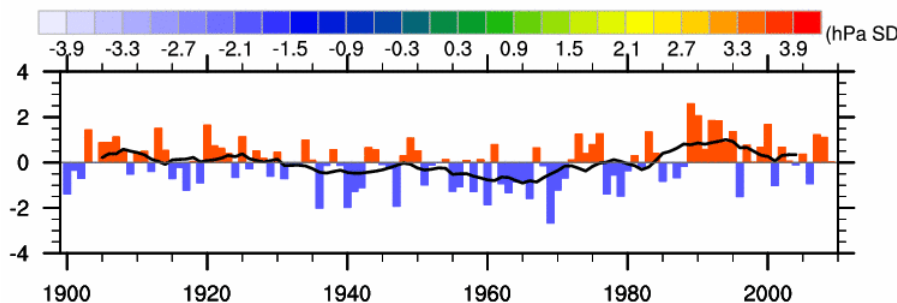
Deser et al. (2011)

North Atlantic Variability

Observations

CCSM4

NAO



Composite Madden Julian Oscillation (MJO)

CCSM4 1° (1980 -1999)

Observed (1980 -1999)

“Compared to other global coupled models, CCSM4 exhibits relatively high skill in simulating intraseasonal oscillations. [It] has pronounced energy in the MJO band and is comparable to the best models [analyzed in Kim et al. 2009]

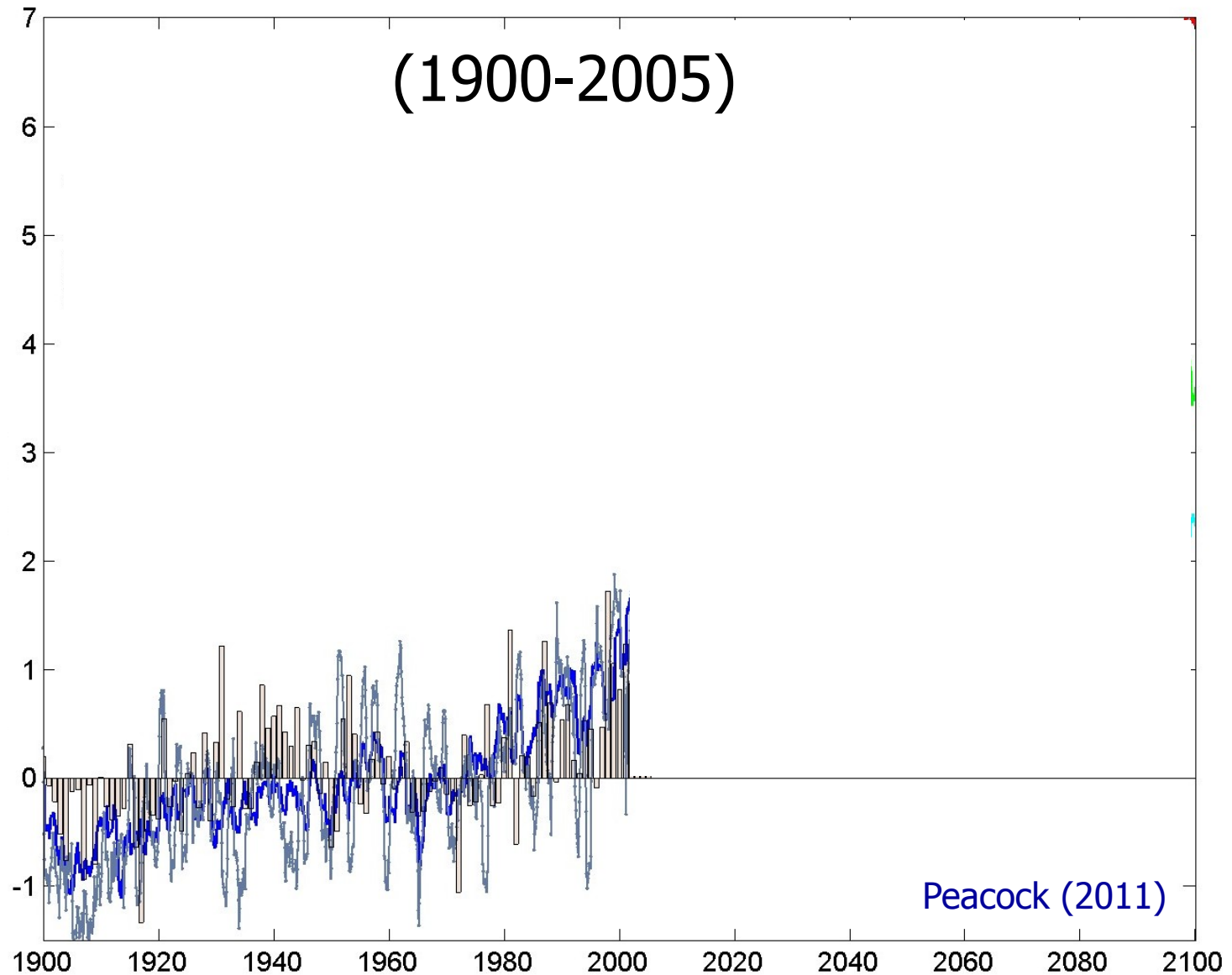
Eight phase composite of OLR (color) and 850 hPa winds

20th Century coupled experiments, Boreal Winter

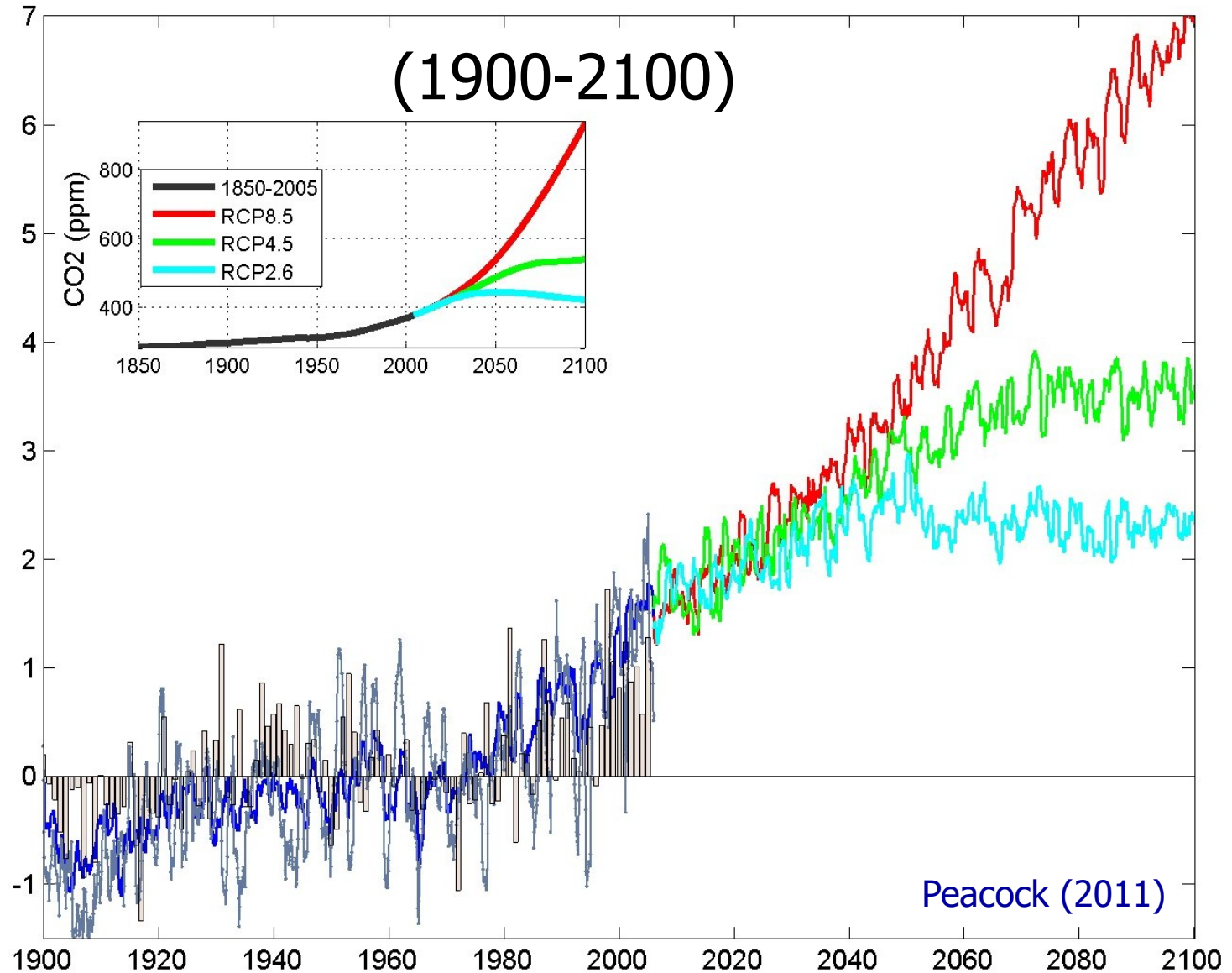
Subramanian et al. (2011)

20th Century and Future Climate

North American Annual Surface T ($^{\circ}\text{C}$)



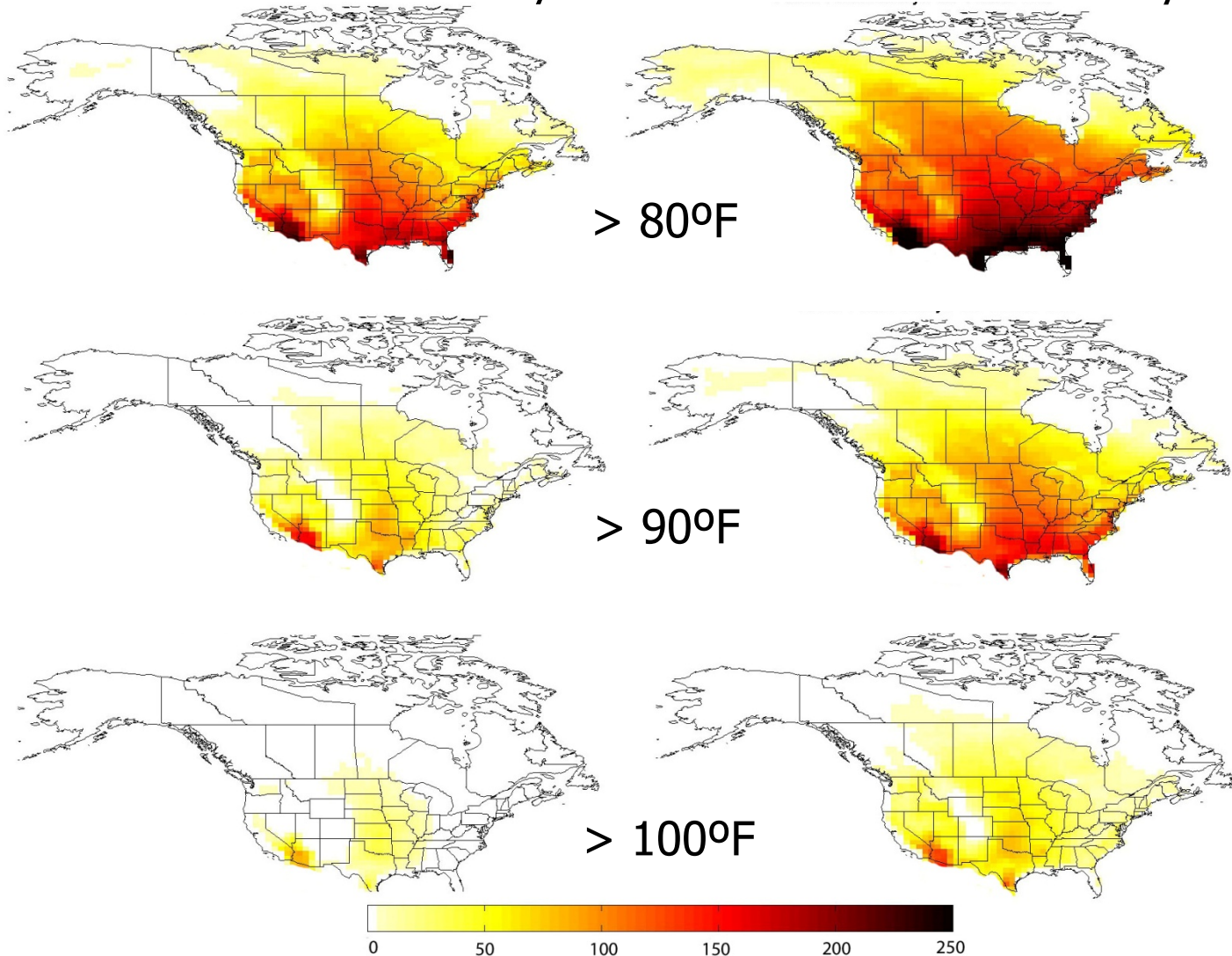
North American Annual Surface T ($^{\circ}\text{C}$)



Extremes: Number of Warm Days

End of 20th Century

End of 21st Century

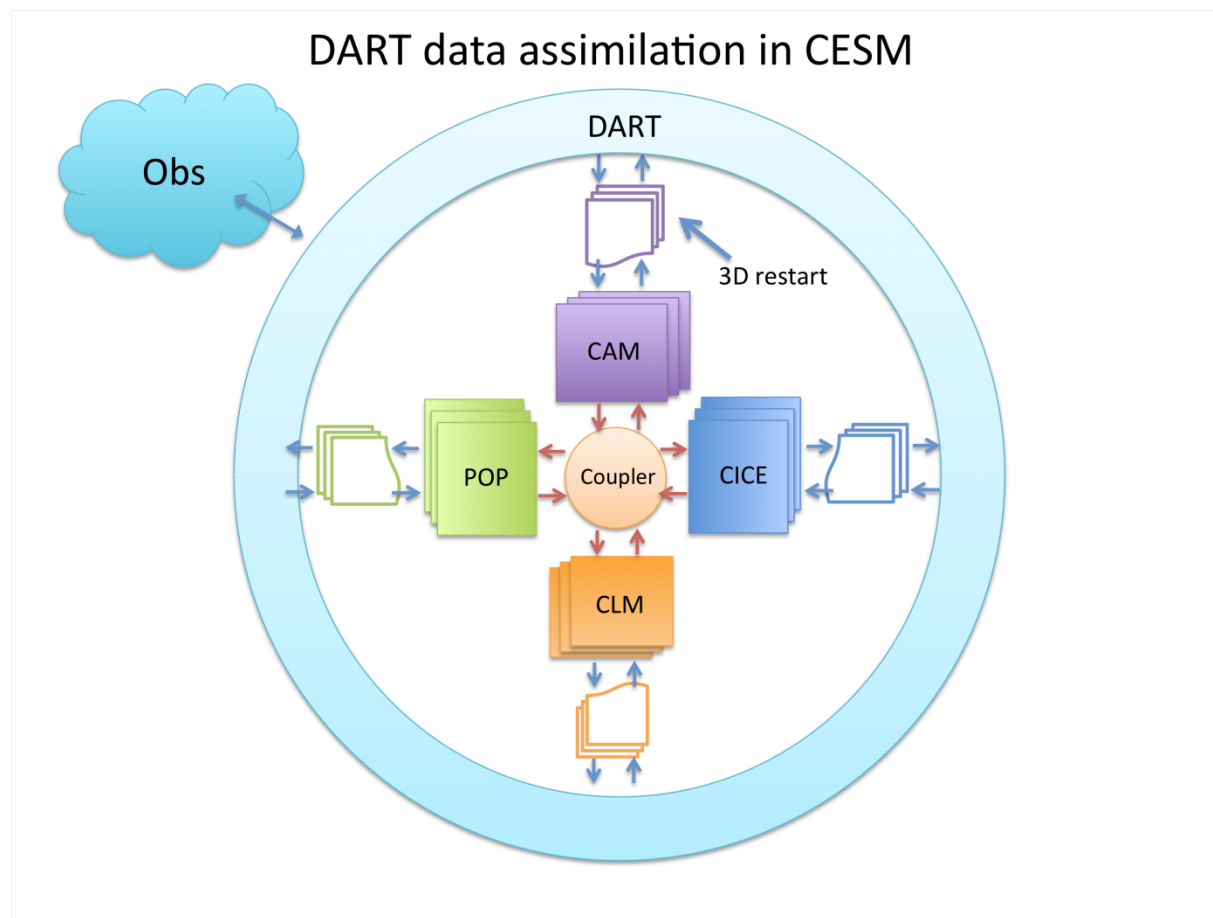


Peacock (2011)

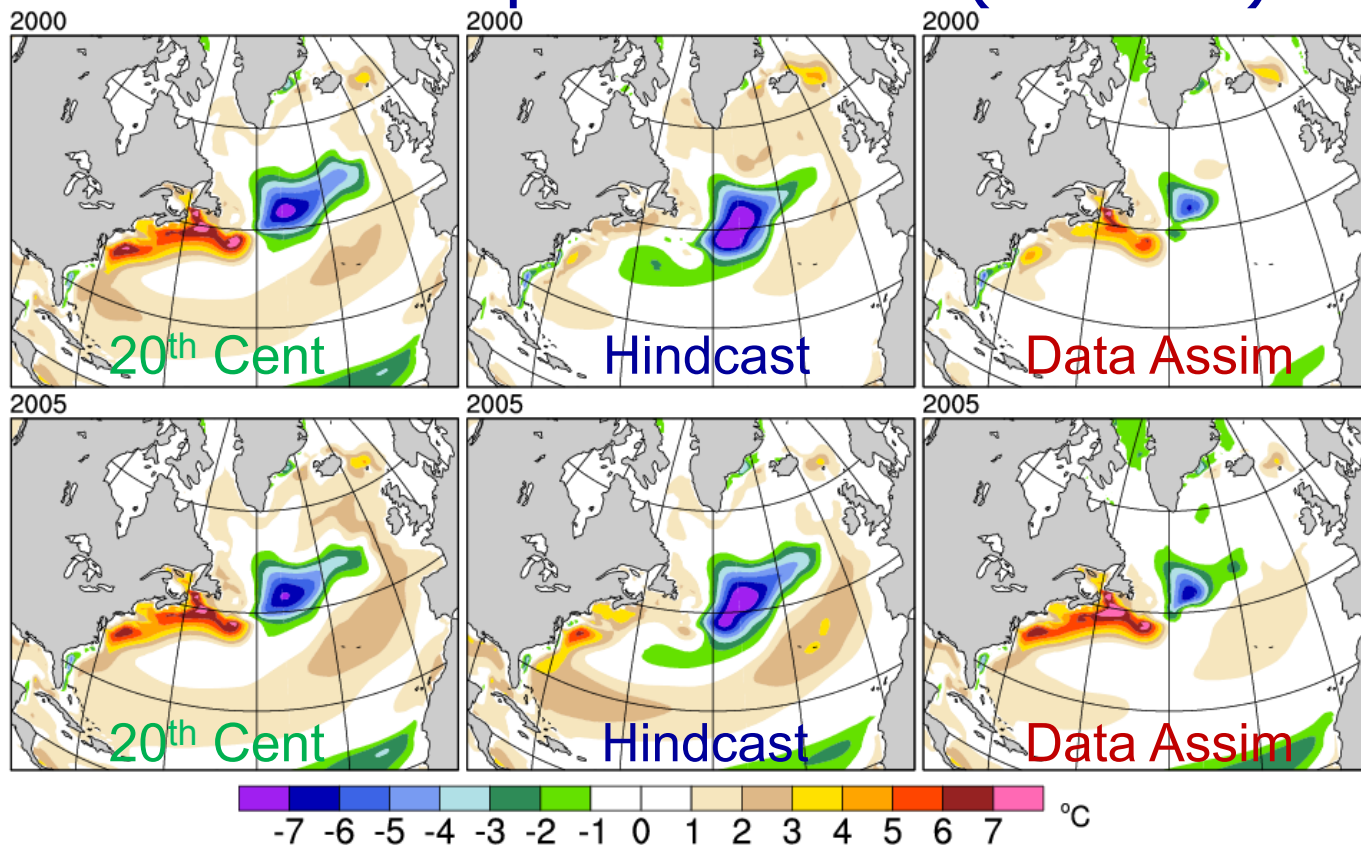
Initialized Decadal Predictions

Interactive Ensembles: Multiple Component Instances and DART

Used for CMIP5 ocean data assimilation – 48 POP instances



Mean Temperature Bias (0-294m)

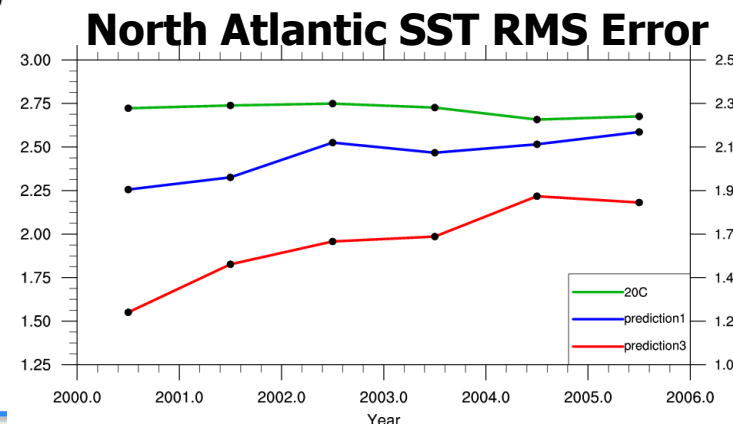


Yr 2000

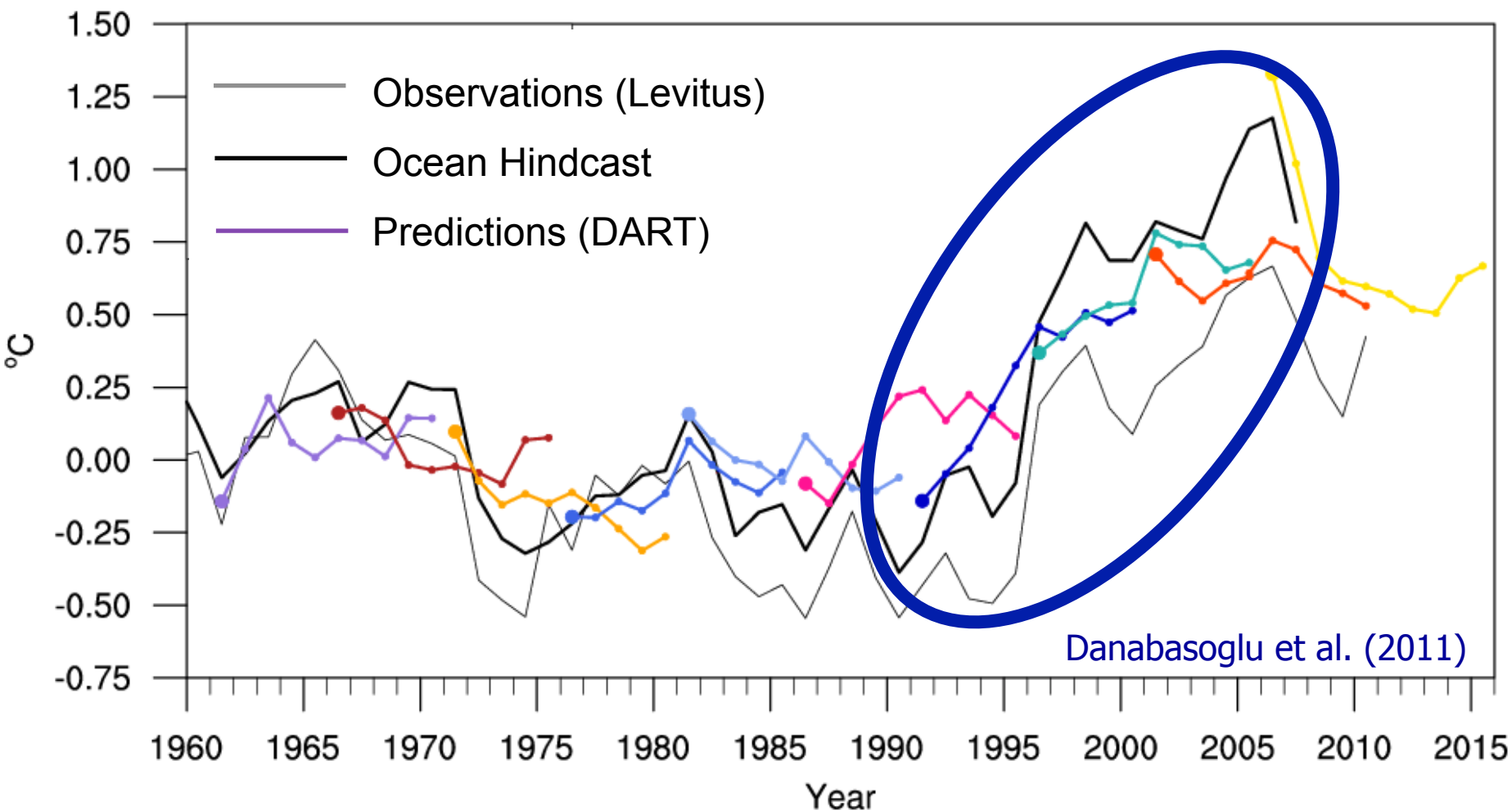
Yr 2005

Persistence of large-scale bias reduction for 5+ years, especially with data assimilation

DART – Anderson et al. (2009); Raeder et al. (2011); Yeager et al. (2011); Tribbia et al. (2011)



North Atlantic: Upper Ocean Heat Content Anomaly



Discernable Predictive Skill

Meeting Community Research Needs

- Developing and supporting an ESM requires a large, dedicated effort. CESM taps into a broader pool of expertise and minimizes duplicative efforts.
- Wide community use of CESM and its data (peer-reviewed journal articles).
- NSF Review: “Unqualified success” pushing the frontier of climate science

Best Practices

- **Openness, inclusiveness and transparency.** Ongoing community access to source code and simulation data; documentation; workshops, etc.
- **Clear and continual communication.** Especially important is frequent communication between scientists developing the model and software engineers: essential for developing a robust code.
- **Strong infrastructure support** (e.g., coupling development; flexible I/O; post-processing and diagnostics; performance tuning; porting; etc.)
- **Multiple levels of rigorous code testing.** This includes testing of the fully coupled system in various configurations.
- **Appropriate reward systems and clear job development paths.**

An Ongoing Challenge

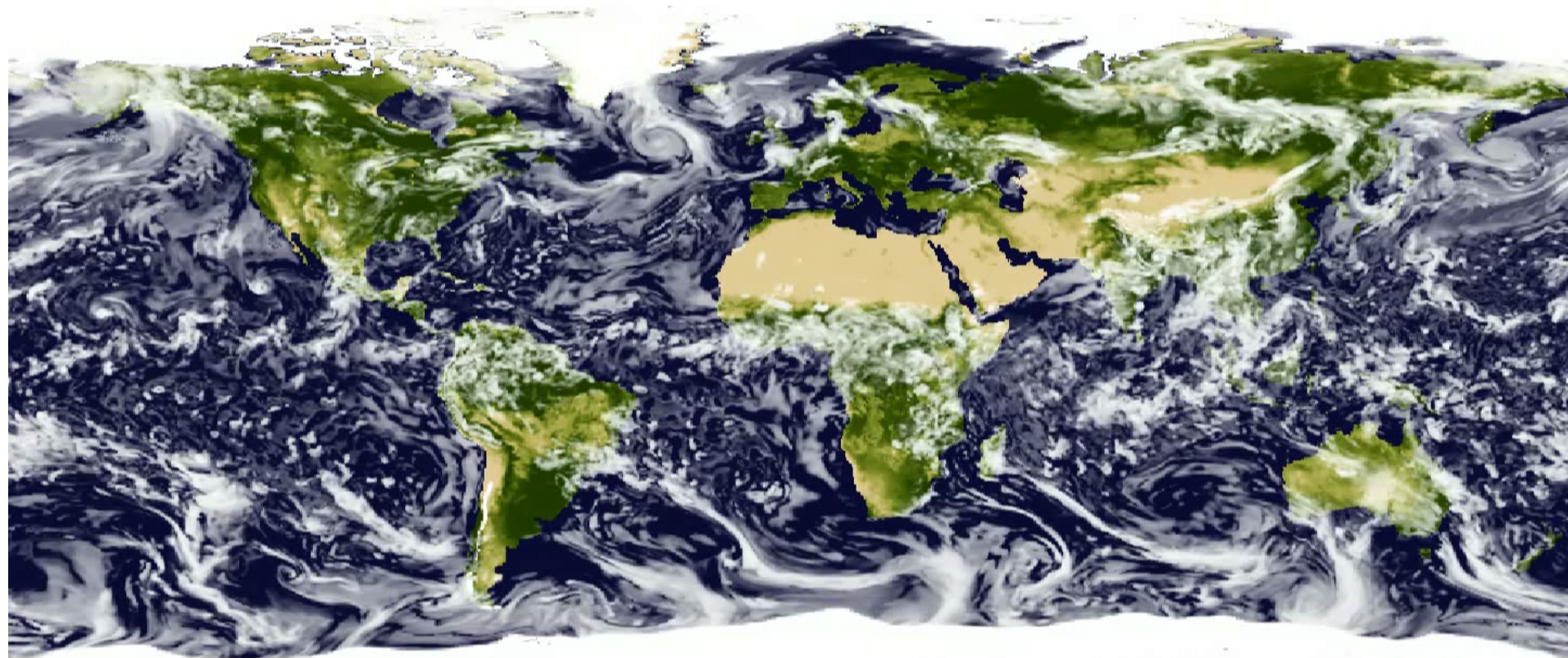
Meeting Research and Model Development Needs

- Rapidly increasing complexity
- New model components and coupling requirements
- Numerous and new grids (e.g., unstructured)
- New capabilities (e.g., data assimilation)

With Simultaneous User Community Needs

- Frequent and fully documented releases
- Multiple platforms; various configurations and resolutions
- Ease of creating “out-of-box” experiments
- Data availability and post-processing capabilities
- Increasingly diverse user community and requirements
- Capacity Building

High Resolution Global Climate Simulations



20 Jul 00 h



NCAR is sponsored by the National Science Foundation